Design of a Remotely Accessible PC based Temperature Monitoring System

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***Abstract* – An innovative data-acquisition circuit for temperature monitoring and control is designed and interfaced to printer port of a web server computer. Further, an interactive web application program has been developed and kept running in the server computer for controlling the operation of the data-acquisition circuit. Authenticated clients can access the web based instrumentation system through Internet / Intranet.**

***Index Terms* – Data-acquisition, client, internet, instrumentation, server, temperature.**

I. INTRODUCTION

In recent times, many researchers have reported several design and implementation schemes for measurement systems that can be accessed through World Wide Web (WWW), as in [1]-[6]. The PC (Personal Computer) based systems reported in [1]-[4] used vendor specific data acquisition hardware and proprietary application software. Embedded based systems given in [5]-[6] are not as powerful as PC based systems, though they have some advantages because of their compactness. The smart phones and PC can not be directly used as clients in [1]-[4] unless the required proprietary runtime software and web browser plug inns have been already installed in them. Further, a conventional web page refreshing technique based on HTML tags and costumed JavaScript is used in the design of the web applications of the above reported works. The conventional web page refreshing technique results in larger volume of data transfer in between a server and concurrent clients in a communication network [7]. So, the reported measurement techniques of [1]-[6] will require much higher data communication bandwidth to achieve acceptable response time in between a server and concurrent users. Besides, these works use a three-tier model for client-server communication process. In their three-tier model, sensors are initially interfaced to a front-end application server unit to carry out data acquisition and control tasks in real time. And, another web server keeps on polling data from the front-end server for processing the client request. Here, the web server acts as an interface in between the clients and the front-end application server. This three-tier model is sometimes not desirable due to the longer response time required for overall data communication process.

The above mentioned disadvantages of the reported works have motivated the present work to propose an innovative measurement system that is based on two-tier client-server model of data communication. The present work also addresses the problems and potential solutions related to accessibility of the conventional web based measurement systems from remote clients. Besides, this paper also describes the design of an innovative all-digital-DAQ circuit to be used for interfacing transducers to the printer port of the server PC.

II. DESIGN METHODOLOGY

A two-tier client-server model of data communication processes through a web application is use to designed and implement the proposed measurement system, as shown in Fig.1.

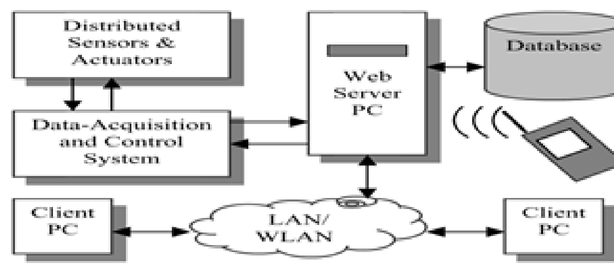

Figure 1. Two-tier client-server data communication model used for remote monitoring and control of sensors and actuators through a LAN and wireless LAN (WLAN).

The server side of the system consists of sensors, DAQ unit and a web server PC. The web server works as an application server as well as local web hosting server. The DAQ unit is interfaced to printer port of the server, and a web application running in the server collects sensor data continuously at regular interval of time. These acquired data are made available to the client machines such as PC and smart phones through WWW. And, the following sections describe the design approaches of the proposed measurement system.

A. Temperature sensing circuit and DAQ unit

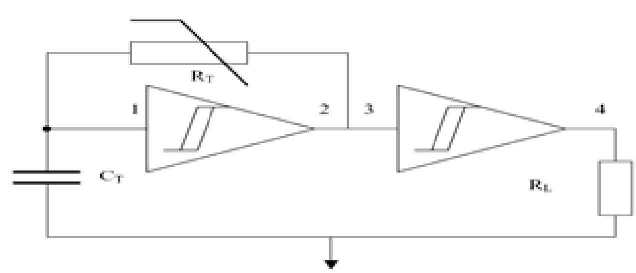

Figure 2. Temperature sensing circuit designed with Schmitt trigger

A temperature sensing circuit is designed by using a temperature sensitive transducer (negative temperature co-efficient thermistor - R_T) in the positive feedback network of an electronic oscillator circuit, as shown in Fig.2. The

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oscillator circuit is designed with Schmitt trigger (IC MM74C14), and the frequency of the TTL compatible (Transistor Transistor Logic) output signal is given by (1), as in [15].

$$f = \frac{1}{R_T C_T \ln\left[\left(\frac{V_{CC} - V_{T-}}{V_{CC} - V_{T+}}\right)\left(\frac{V_{T+}}{V_{T-}}\right)\right]} \tag{1}$$

Where, R_T is the resistance of the thermistor and C_T is the value of the timing capacitor used in the circuit. V_{T-} and V_{T+} are respectively the lower and the upper triggering threshold voltages of the Schmitt trigger when the power supply V_{CC} is at +5V DC.

The output of the sensing circuit is fed to a DAQ circuit interfaced to data lines of the printer port of a web server PC. In the present DAQ, ADC (Analog to digital converter) chips are not used, and the DAQ unit consists of a buffer gate (IC_1) digital control gate (IC_2) an 8-bit asynchronous ripple counter, as shown in the functional block diagram of Fig.3. This design concept results an innovative all-digital-DAQ circuit that accepts digital input and provides digital output.

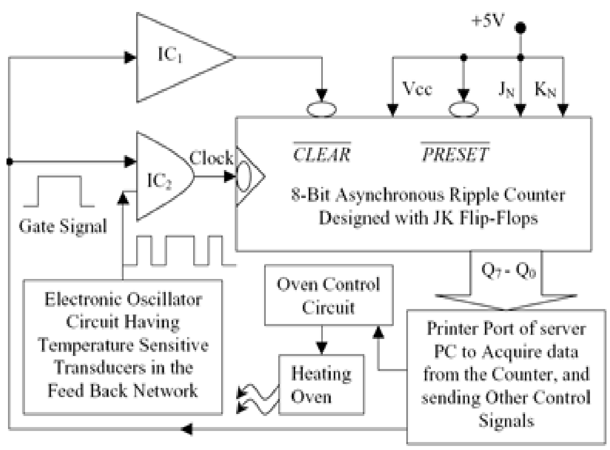

Figure 3. Functional block diagram of the DAQ unit designed for the present work

In the DAQ circuit, IC_2 generates clock signal of the counter by obtaining Gate/Clear signal from the printer port of the server PC via a control signal line. This control signal is generated automatically by a web application running in the server PC. The IC_2 allows the up-counter to increment its count value proportional to the number of pulse transitions of sensor output during the HIGH logic state of Gate/Clear signal. Then, the server PC reads the digital output of the counter just before resetting the counter. The counter will be cleared when LOW logic state of the Gate/Clear signal arrives. Theoretical timing diagram of the digital signals involved in the operation of the digital DAQ is given in Fig.4.

If T_{ON} is the pulse duration of the Gate/Clear signal in HIGH logic state, and T_S is the total time period of the sensor signal then maximum (C_{MAX}) and minimum (C_{MIN}) digital count values are obtained from (2) and (3).

$$C_{MAX} = \frac{T_{ON}}{T_{S(MIN)}} \tag{2}$$

$$C_{MIN} = \frac{T_{ON}}{T_{S(MAX)}} \tag{3}$$

Here, $T_{S\,(MAX)}$ and $T_{S\,(MIN)}$ are the time periods of the sensor output signals at the highest and lowest frequencies of the sensing oscillator circuit. The DAQ program is written in such a way that it maintains a specific value of T_{ON} respect to $T_{S\,(MAX)}$ and $T_{S\,(MIN)}$, so that the count value must be in the range given by (4) to prevent automatic roll-over of count value from $(255)_{10}$ to $(0)_{10}$.

$$(0)_{10} \le C_{VALUE} < (255)_{10} \tag{4}$$

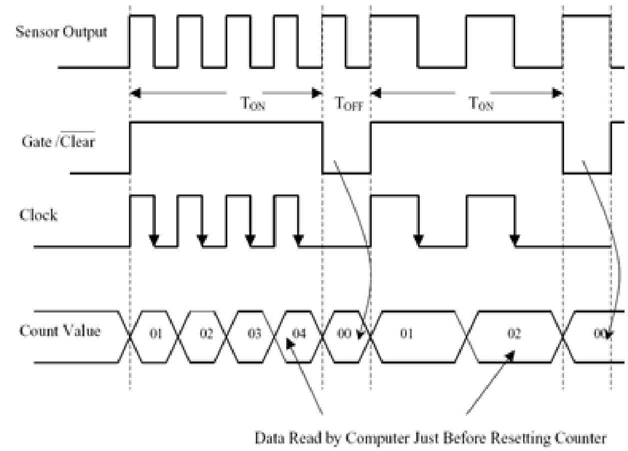

Figure 4. Timing relationship of different signals of the DAQ unit

B. Development of the web application for user interface

In the present work, an interactive web application web application is developed by using Microsoft's ASP.NET AJAX web controls of Visual Studio 2010. ASP stands for *Active Server Pages* and ASP.NET web applications work by using .NET (*Dot NET*) framework. This framework utilizes resources of the host operating system, and gets access to the hardware of the host computer by using .NET libraries [8]. And, AJAX (**A**synchronous **J**avaScript and **X**ML) is an inbuilt extension to ASP.NET 3.5 and 4.0. It makes a web application highly interactive and gives the feeling of classic desktop applications while viewing web pages [8]. In the AJAX paradigm, web applications work by exchanging specific data of the web page rather than that of the whole page in between a server and clients. This results in faster response time unlike the conventional web applications.

In the present web application, Visual Basic.NET (VB.NET) is used as programming language, and Fig.5 shows the architectural hierarchy of the .NET controls used in the web application. The AJAX timers and update panels are included to enable partial web page update events of the interactive web page, while *Script Manager* enables AJAX functionalities in the web page. A master AJAX timer controls all the events of the web page, and the web application runs continuously by checking the presence of incoming client request all the time. Fig.6 shows the flowchart of the main web application program designed in the present work. This web application will again call another subroutine program, shown as flowchart in Fig.7, to control the DAQ circuit. The printer port of the server computer is accessed from the web

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application program by using a dynamic link library (DLL), as in [9]-[10]. This DLL file is to be kept under System32 of Windows directory in Windows 98/2000/XP. Fig.7 shows the self explanatory flowchart of the DAQ program.

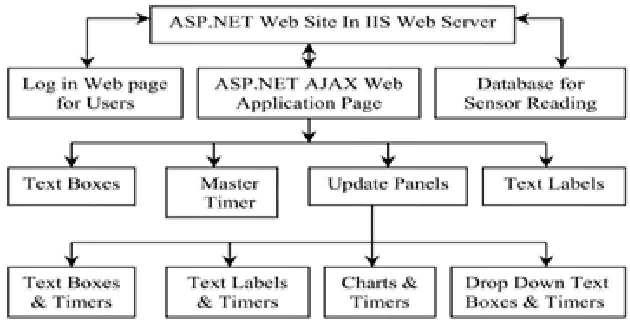

Figure 5. Architectural hierarchy of the web application

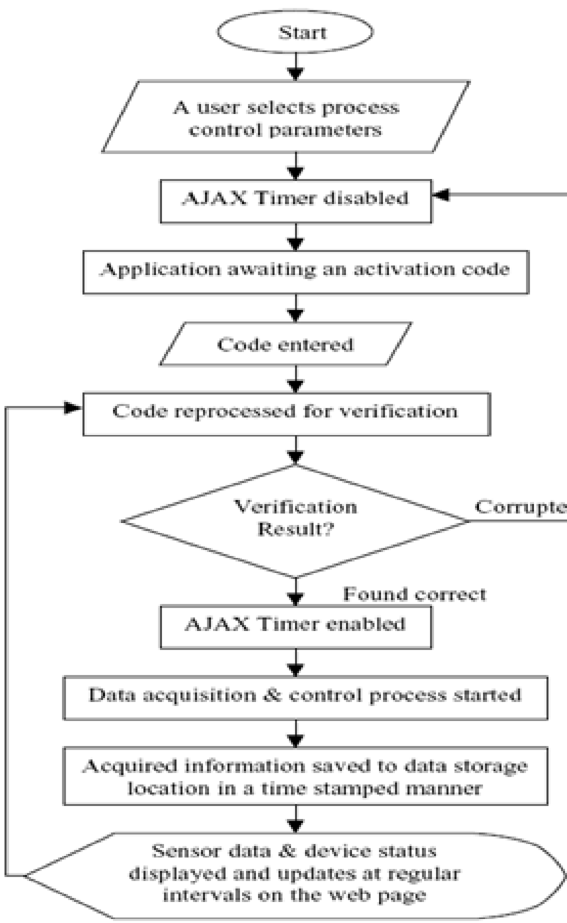

Figure 6. Flowchart of the main web application program

III. The Configuration of Server and Clients

A PC having Windows XP Professional Service Pack 3 is configured as wired local web server by installing and configuring IIS prior to installation of .NET Framework 4.0, as in [7] and [8]. This server is connected to a Gigabyte Ethernet switch together with a 100 Mbps WLAN access point and clients machines. The simplified functional block diagram of the client-server network configuration is shown in Fig.8.

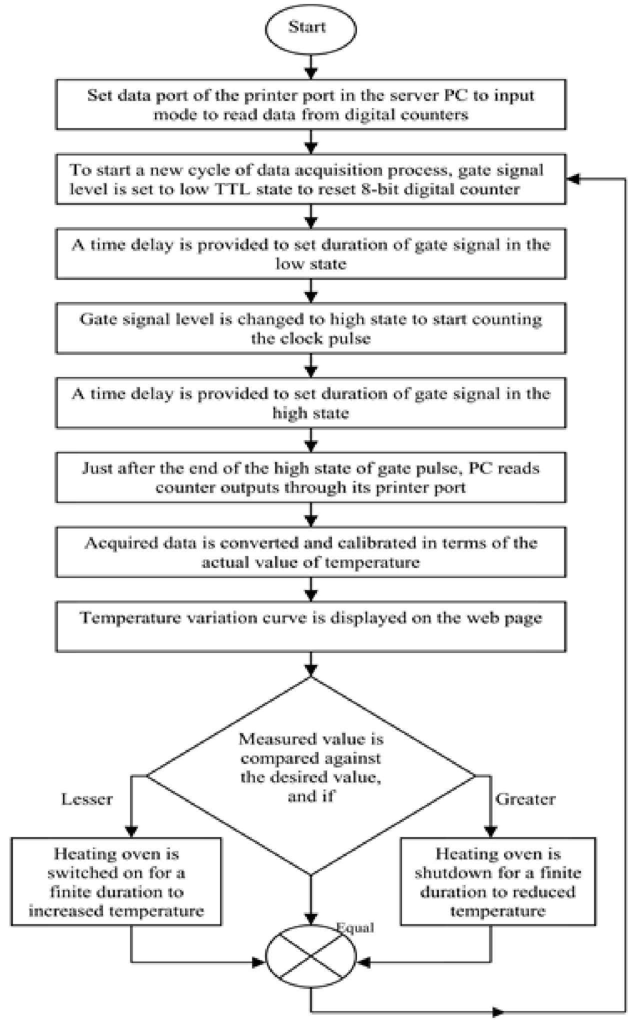

Figure 7. Flowchart of data acquisition and control subroutine

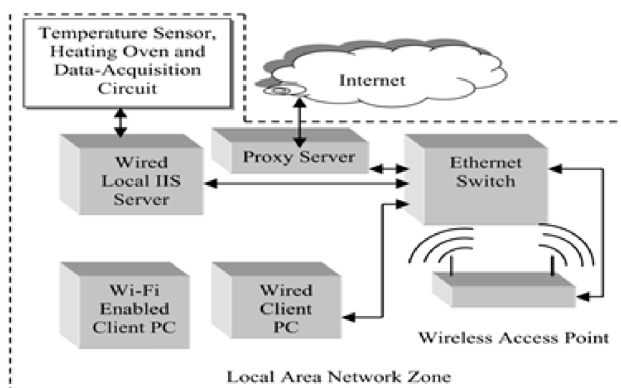

Figure 8. Client and server configuration of the measurement system

IV. Experimental Observations

A. Sensor circuit and DAQ hardware

Frequency versus temperature variation of the oven is recorded manually by heating the transducer of the sensing oscillator circuit. The calibration curve is shown in Fig.9. The non-linearity of the response is due to the absence of transducer linearizing circuits in the electronic instrumentation system. A standard temperature sensor and a frequency

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counter are used to record variation of oscillator signal frequency with temperature.

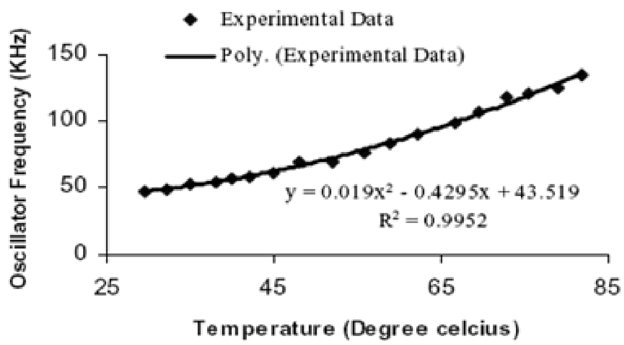

Figure 9. Calibration curve of the temperature sensing circuit

Further, a behavioral VHDL description program is developed and run to simulate the all-digital-DAQ in Actel Libero v9.1, and its functionality is verified with Actel Fusion Embedded Development Kit - M1AFS. Fig.10 shows the signal timing diagrams of the DAQ obtained from VHDL simulation.

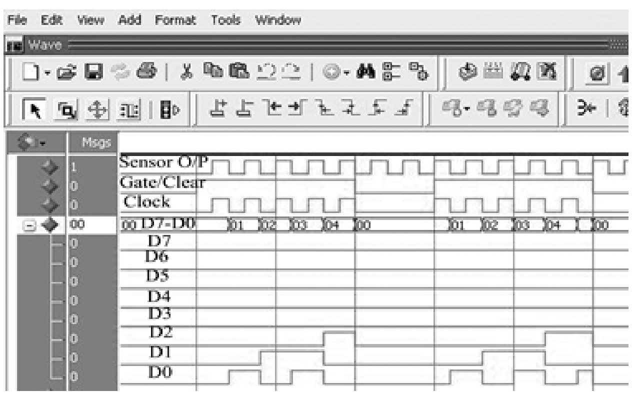

Figure 10. Signal timing diagram of the all-digital-DAQ obtained from VHDL simulation

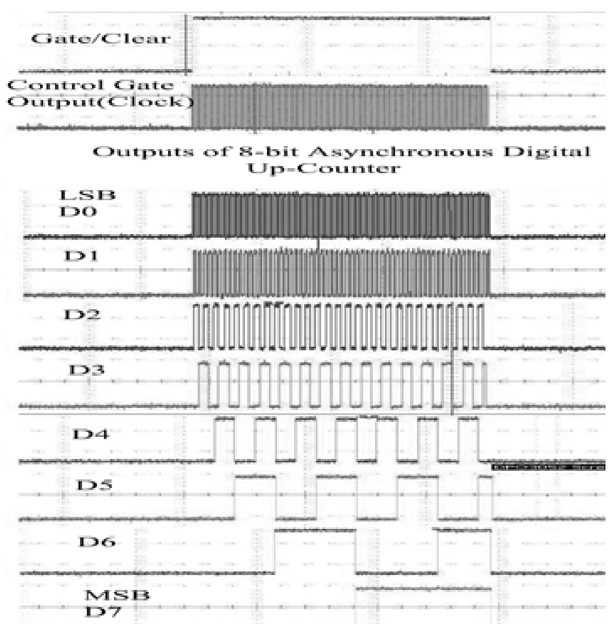

Figure 11. Merged timing diagram of the signals in the all-digital-DAQ as obtained experimentally from a dual channel DPO (Recorded from Digital Phosphor Oscilloscope; Model: Tektronix TDS 3052, 2.5 GS/Sec).

Further, the timing diagram of the signals in the DAQ circuit is examined and traced experimentally from a digital oscilloscope, as shown in Fig.11. These traces are taken at room temperature and frequency of the sensor output signal is set to 40 KHz, and frequency of the control gate signal used is 200Hz.

B.Remote accessibility of the measurement System

The interactive web page developed for the proposed measurement system is browsed by using a unique local website address known to all the clients in the LAN/WLAN of our laboratory. Fig.12 and Fig.13 show the snapshots of the web application page browsed from two client machines. We deliberately use clients having Operating systems different from that of the server PC to check cross platform interoperability of the web application.

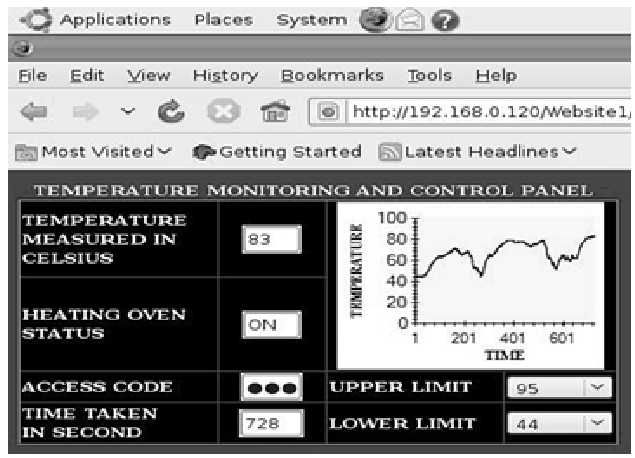

Figure 12. Temperature monitoring and control from a Linux client

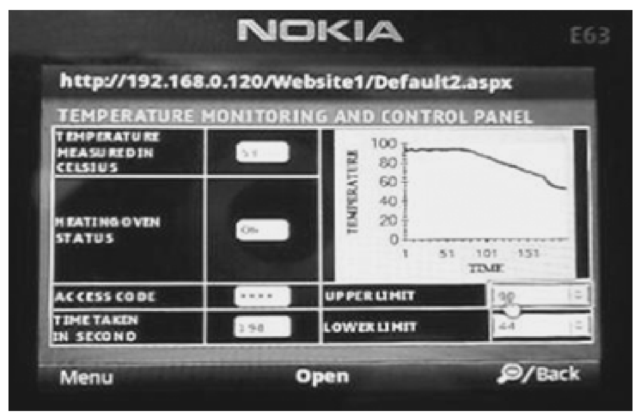

Fig.13. Temperature monitoring with a Nokia Smart Phone-E63.

V. Results And Discussion

Temperature has been monitored and controlled successfully through an ASP.NET AJAX web application by using client machines having different operating systems without having to install runtime software and plug inns to them. Further, there is no significant web page flickering during refreshing and data update operations of the web application in client PCs, which is because of the ASP.NET AJAX features incorporated in the design of the present web application. A slight flickering effect is observed in the web page during each refreshing cycle in smart phones. This happens since

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mobile web browsers are not as powerful as that of PCs at present time [11]. A client scheduling server, if included in the network configuration, will enable multiple clients to access the web application on priority basis, as in [1].

The temperature sensing circuit of the present work works very well from room temperature to around 95^0C. The DAQ works in good agreement with the VHDL simulation result obtained. The present DAQ unit does not require a dedicated ADC chip at all. So, this design technique can avoid some of the stringent requirements and complexity of designing analog signal conditioner circuits, which are normally required when ADC chips are used in DAQ unit [16]. Data acquisition speed of the present DAQ is limited by frequency of the control gate signal, and an error of ±1 LSB (Least Significant Bit) is found in the experimental observation. Being a fully digital system, this DAQ can be directly fabricated in the form a reconfigurable unit by implementing the entire DAQ circuit in the field programmable gate array (FPGA) chips. Future scope of the present work is to develop remotely accessible FPGA based sensor network for use in industrial applications. And, evaluation and optimization of the system performance indices such as response time, throughput, bandwidth utilization factor etc. will be carried out by using standard testing tools.

CONCLUSION

The present work has implemented an innovative and remotely accessible temperature monitoring system. The novelty of the proposed system lies in its simplicity of design, use of vendor independent hardware, and accessibility of the system through a LAN or WLAN in real time.

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